Intertwined carrier and field dynamics in 2D semiconductor photonic crystals

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One of the particularities of semiconductor 2D Photonic Crystals (2D PC) is the presence of high Q resonances corresponding to low group velocity modes at the band edge[1]. This gives photon lifetimes which are fairlly long, of the order of a few picosecond. Moreover, in semiconductor 2D PC structures with hole lattice the carrier relaxation time is shorter than in the bulk material due to the faster recombination time in the air/semiconductor interfaces. The combination of these two features results in the photon lifetime within the resonator becoming non-negligeable with respect to the carrier relaxation time. Under these conditions the carrier dynamics is expected to affect the field evolution within the resonator when the two relax freely. In this work we put into evidence the subtle interplay between the carriers and field in the time scale of the photon lifetime by means of femto second pump and probe experiments.
We show that for pump-probe time delays of the order of the photon lifetime, the reflected probe signal manifests spectral oscillations as the system is pumped close to laser threshold. We link these oscillations to the frequency chirp due to fast carrier recombination in the early stages just after the arrival of the pumping pulse. An accurate theoretical analysis based on mean-field equation for slowly varying amplitude of the elctric field coupled with the carrier evolution equation describes the complex system closely and allows us to extract relevant parameters related to the material and photonic confinement.

[1] C. Soukoulis, “Photonic crystals and light localization in the 21st century", edited by Kluver Academic Publishers, Boston, 2001.